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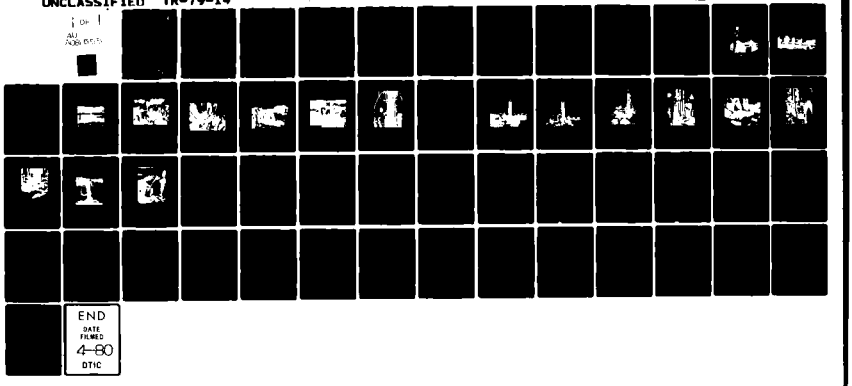

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# TECHNICAL REPORT 79-14

## FINAL REPORT
## CONTRACT FO8606-79-C-0023



TELEDYNE GEOTECH

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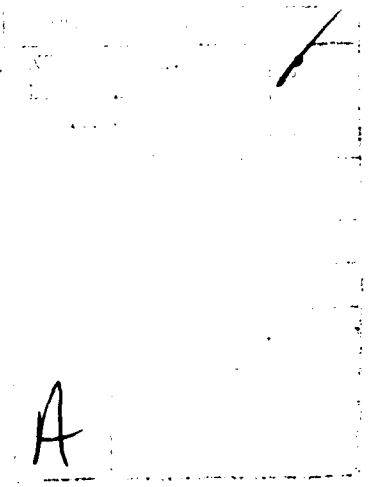
TECHNICAL REPORT 79-14

FINAL REPORT
CONTRACT F08606-79-C-0023

by

W. D. Ballard



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TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas 75041

15 November 1979

## ABSTRACT

This report describes the work performed to purchase, improve the transportability and evaluate a lightweight air percussion drill rig for use in preparing 50-foot deep (15 meter) boreholes cased with 4.5 inch O.D. casing. The drilling rig was purchased from a foreign manufacturer and modified to incorporate dual purpose carrying handle and wheel axle stubs on the major rig components. Other components and modifications to improve transportability and field performance were also purchased or fabricated. A preliminary evaluation of the equipment at the Teledyne Geotech plant showed that air percussion drilling could not be used in either soft geological formations or where there is subterranean water present. A subsequent field evaluation showed that the equipment was entirely satisfactory for use in hard geological formations and met or exceeded all specified requirements during these tests. A test borehole was completed to 85-feet (25 meters) with an average penetration rate of six to eight inches-per-minute. Three minor problems encountered during the field tests were subsequently corrected.

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FINAL REPORT
CONTRACT F08606-79-C-0023

## 1. INTRODUCTION

The purpose of the work under this contract was to purchase, evaluate and test a hand transportable drilling rig capable of drilling a 5.25 inch borehole up to 50 feet deep in hard rock. As part of the performance evaluation, modifications as required to improve the transportability of the equipment were designed and incorporated.

This work was performed during the period from 4 April through 4 November 1979. The program was directed by the Air Force Technical Applications Center, 1035 TCHOG/TGP, Patrick AFB, FL. The Teledyne Geotech Program Manager was Mr. W. D. Ballard. Other principal contractor participants in the project were Mr. F. M. Hennen, Mr. W. C. Grosskopf, and Mr. J. E. Poetschke.

## 2. SUMMARY OF TASK EFFORT

The contract consisted of the following major tasks:

4.1.1 The contractor shall purchase, accept, evaluate, test, maintain, and ship a hand transportable drilling rig capable of drilling 5.25 inch boreholes up to 50 feet deep in hard rock. The tilt of the borehole will not exceed 7.5 degrees of vertical. The contractor shall purchase the drill equipment only if it meets the specified performance requirements. These requirements shall be verified by inspection and demonstration of equipment as necessary prior to purchase.

4.1.2 After purchase and acceptance of the drilling rig, the contractor shall conduct a thorough evaluation of its performance under actual field conditions. Simultaneously with the field evaluation, the contractor shall design and fabricate or purchase any special tools and/or fixtures needed to complete borehole installations using this equipment.

4.1.3 Using the procedures established during the evaluation phase, the contractor shall drill, case, check the verticality, and cement a borehole in hard rock as a "dress rehearsal" test conducted at Ft. Sill, Oklahoma. The hole will be drilled to a depth of 50 ft. using a 5.25 inch bit and the hole will be cased using 4 inch I. D. pipe.

4.1.4 At the conclusion of task 4.1.3 the contractor shall submit a one-time letter report covering all facets of work completed under this task.

## 2.1 PURCHASE OF DRILLING EQUIPMENT

On 16 April 1979, Mr. W. D. Ballard visited Brisbane, Australia to discuss and finalize the configuration of the drill rig with the manufacturer. The purchase order for the rig and its accessories was released during this visit. Arrangements were made for a Teledyne Geotech representative to receive operator and maintenance training on the equipment at the manufacturer's facility upon delivery of the rig. The rig was shipped via Air Freight, prepaid, to the Teledyne Geotech plant in Garland when the training was completed and the equipment accepted. Mr. W. C. Grosskopf visited Brisbane from 18 through 21 June 1979 to receive operation and maintenance training and to accept the rig.

A standard Jacro[1] Model 350 Drilling Rig was modified by the manufacturer for this application as follows:

- The mast raise rams and their pneumatic controls were removed.
- The auxillary winch and its pneumatic control were removed.
- The standard diesel power plant was replaced with a 40 horsepower, Volkswagen, air-cooled, gasoline engine.
- The drive head was enlarged to increase its bore diameter so that air circulation could be used.
- The derrick panels were made with weight reduction holes added.
- The size of the drill stem guide at the base of the derrick was increased to accommodate a larger drill stem.
- An air manifold to accommodate multiple air compressors was added to the the rig substructure.
- A special light-weight crown block was designed and provided.

---

[1]Purchased from Seismic Supply International, 193 Mary Street, Brisbane Q. Australia.

Figure 1 shows the assembled rig in operation and figure 2 shows the four air compressor units which provide the air to operate the air hammer and maintain circulation.

The equipment was received at Teledyne Geotech on 13 July 1979. A thorough inventory and inspection of the shipment revealed the following:

- All oil fill and fuel tank caps missing.
- An air tank pet cock missing on one compressor unit.
- Several spare components missing from the spare parts kit.
- The fuel control valve on one compressor unit damaged.
- Surface corrosion on the starter assembly of one compressor unit caused by spilled battery acid.

All missing or damaged components were replaced or repaired at the Geotech plant.

## 2.2 MODIFICATIONS TO IMPROVE TRANSPORTABILITY

Upon receipt of the drilling equipment at the Geotech plant, work began on the design and implementation of modifications to improve transportability. These modifications include:

- The incorporation of dual purpose carrying bar and wheel mounting axle stubs on the substructure, compressor units, main engine, derrick and control unit. (Carrying bar and wheel axle stubs were added to the control unit when it was determined, by actual weight tests, that the substructure was too heavy to hand carry with the control unit mounted). Skid assemblies were also added to the compressor units and control unit so that these units could be left unattended on their wheels.
- The installation of quick disconnect steering handles on the main engine, derrick, substructure, and control unit.
- The replacement of the plastic air pressure control lines on all compressors with copper tubing. This change was made to reduce the susceptibility of these lines to damage caused by handling under field conditions.

In addition to the above modifications, the following changes and/or components were incorporated under this task to support the field use of the equipment.

- Screw type leveling jacks were incorporated as an integral part of he carrying bar and wheel mounting axle assemblies used on the rig substructure. These jack screws are used to adjust the rig to achieve borehole verticality.
- Running time meters were added to the compressor units to facilitate maintenance.
- A Tachometer was added to the main engine to assure that adequate hydraulic pressure is maintained at the drive head.
- A slips bowl and cuttings deflector were designed and fabricated.
- A slips adapter was made for the NW drill rod used to push down the cement wiper plug when completing the borehole.
- Slips clamps were designed and fabricated for both the HW casing and the NW drill rod (Diamond Core Drilling Industry Standard).
- A dump bailer for use during the installation of the bottom-hole finishing cement was fabricated.
- Hold-down devices to anchor the rig were fabricated and installed.
- A pipe rack to hold the drill casing and push rods was designed and assembled.

Also under this task, the hand tools and expendable supplies such as the drill casing, lubricants, oils, cement, etc. were purchased.

The final weight of the major components of the drill rig after modification were as follows:

| | |
|---|---|
| Derrick | 510 pounds |
| Main Engine | 500 pounds |
| Substructure | 440 pounds |
| Control Unit | 240 pounds |
| Compressor | 425 pounds |
| Hydraulic Oil Tank | 250 pounds |
| Drive Head | 160 pounds |

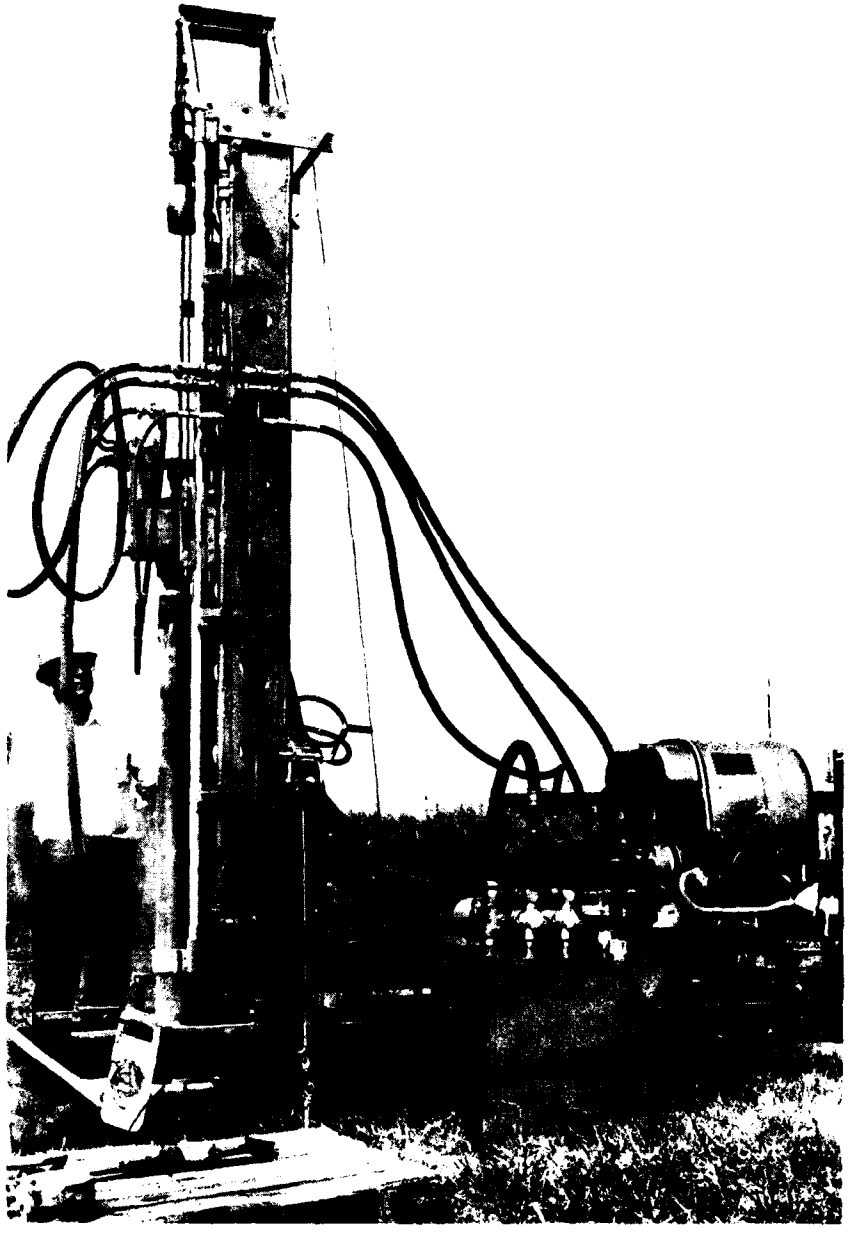

Figure 1. Modified Jacro Model 350 Drilling Rig

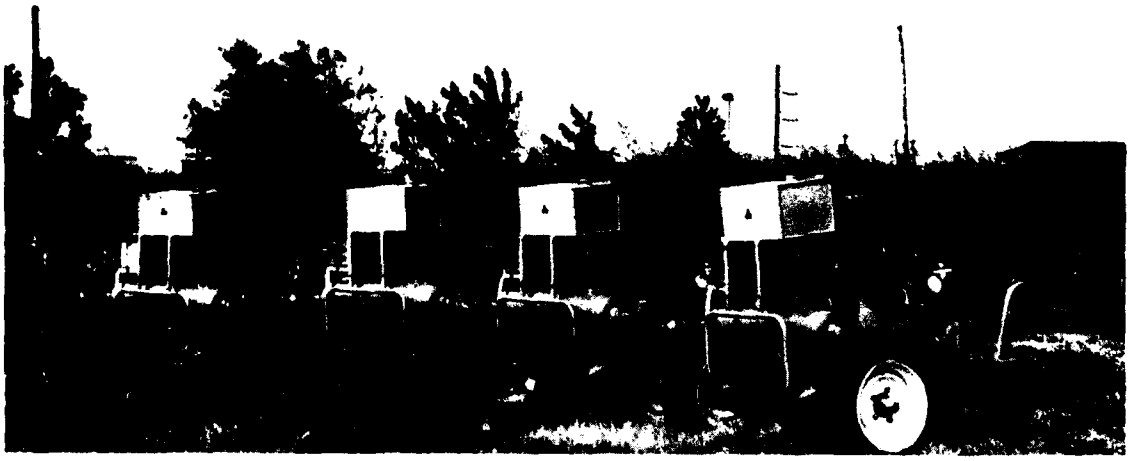

Figure 2. Air Compressor Units Used to Provide Air for Hammer Drill and Circulation

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## 3. TEST AND EVALUATION

### 3.1 IN-PLANT EVALUATION

A preliminary evaluation of the equipment was conducted at the Teledyne Geotech plant on 12 and 13 September 1979. A borehole was started using a 5-1/4-inch stepped drag bit for initial penetration of the overburden. At a depth of approximately five feet, the hammer drill was rigged to test its performance in a soft medium. It was quickly determined that the hammer drill could not be used in this type of material because the amount of crowd required to operate the hammer caused the bit to auger into the material and resulted in a loss of air circulation. The reduced flow of air halted the operation of the hammer and increased its tendency to auger. In addition, ground water would tend to collect in the borehole in significant amounts whenever drilling was halted to change bits or add drill stem. As the depth of the borehole increased, this water combined with the finer particles in the cuttings and became a very thick, adhesive mud which was dried by the extremely hot air used for circulation. Continued penetration was accomplished by alternating the use of the drag bit and hammer drill, however, at a depth of approximately 27 feet, circulation was permanently lost. The hammer was retrieved from this depth with considerable difficulty and it was decided that continued drilling under these conditions was impractical. Further testing of the drilling equipment and borehole completion techniques was rescheduled for the field tests to be conducted at Fort Sill, Oklahoma.

### 3.2 FIELD TESTS

On 26 and 27 September 1979, the drill rig was again assembled and disassembled to verify its transportability and on 28 September, all of the equipment and material needed to complete the field tests was loaded on rental trucks for transport to the test site. The Fort Sill, Oklahoma area was selected for these tests because a hard geological formation was accessable near the surface of the ground.

Access approval was obtained from Fort Sill officials and a drilling site was selected on 2 October 1979. Figure 3 shows the location of the borehole site. An area large enough for the rig substructure was leveled by hand and the rig was assembled. Figure 4 shows the rig substructure being positioned at the borehole location. Figures 5 and 6 show the control unit and derrick, respectively, installed on the rig substructure and figure 7 shows the installation of the main engine.

After the rig was assembled and the compressor units positioned, the drive head, hydraulic fluid reservoir, and all lines were installed and connected. The temporary anchors and rig hold-downs were then installed but not tightened.

The main engine was started and the catline and catline adapter installed. The drag bit and drill collar were rigged and the drill collar was lowered into the derrick guide shoe. The rig was leveled using the jack screws to plumb the drill collar to a vertical position as shown in figure 8.

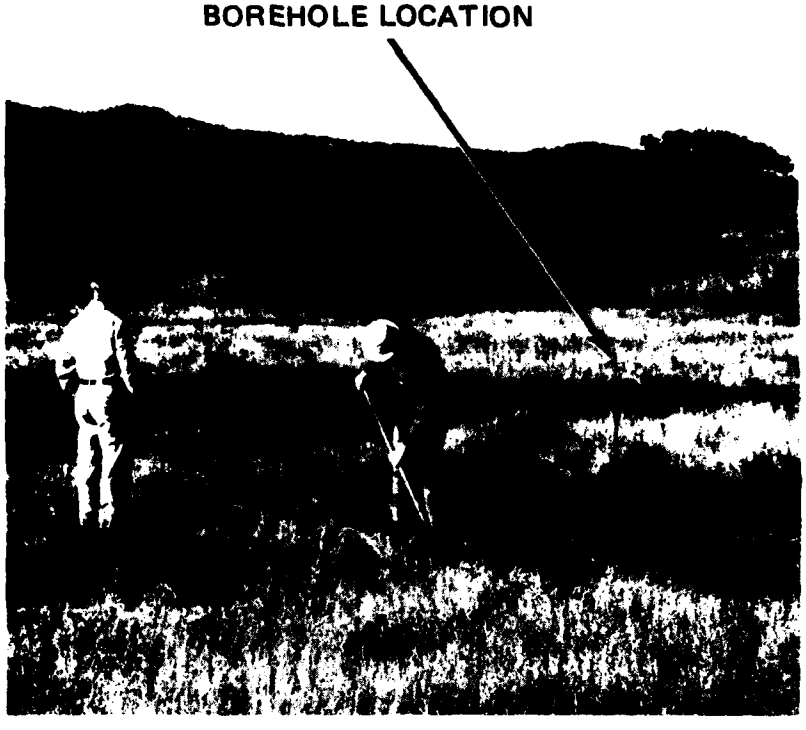


Figure 3. Borehole Site Location for Field Tests

Figure 4. Positioning the Rig Substructure. The Drive Head is Visible in the Background

Figure 5. Mounting Control Unit on Substructure

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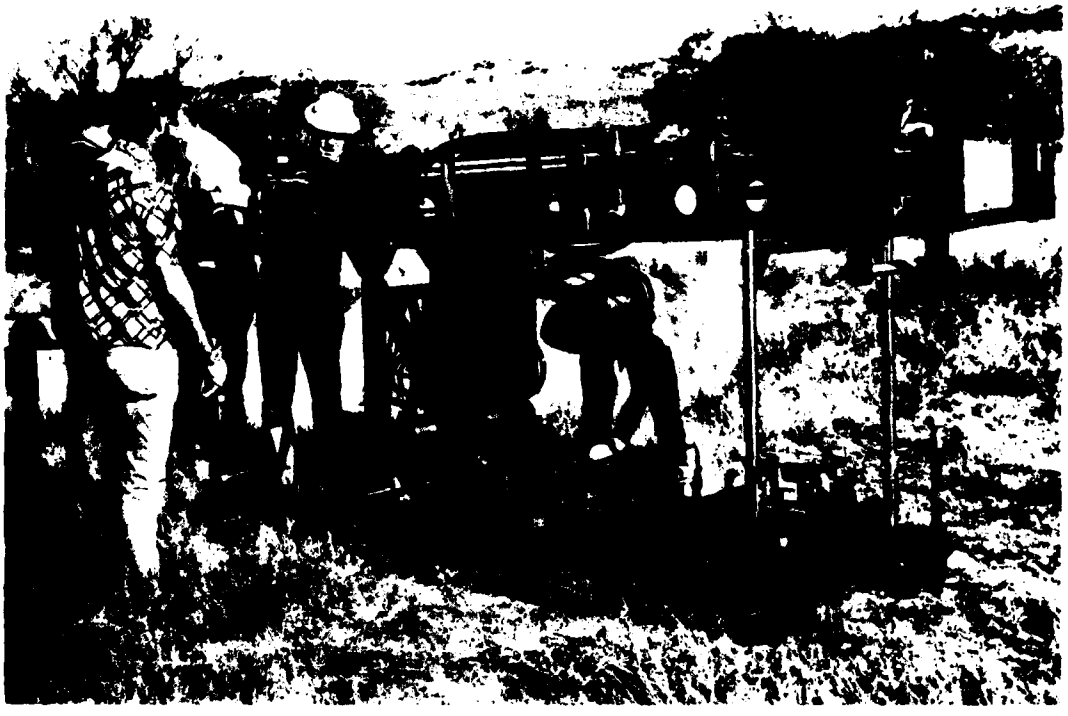

Figure 6. Derrick Installed in Folded Position


Figure 7. Installation of Main Engine

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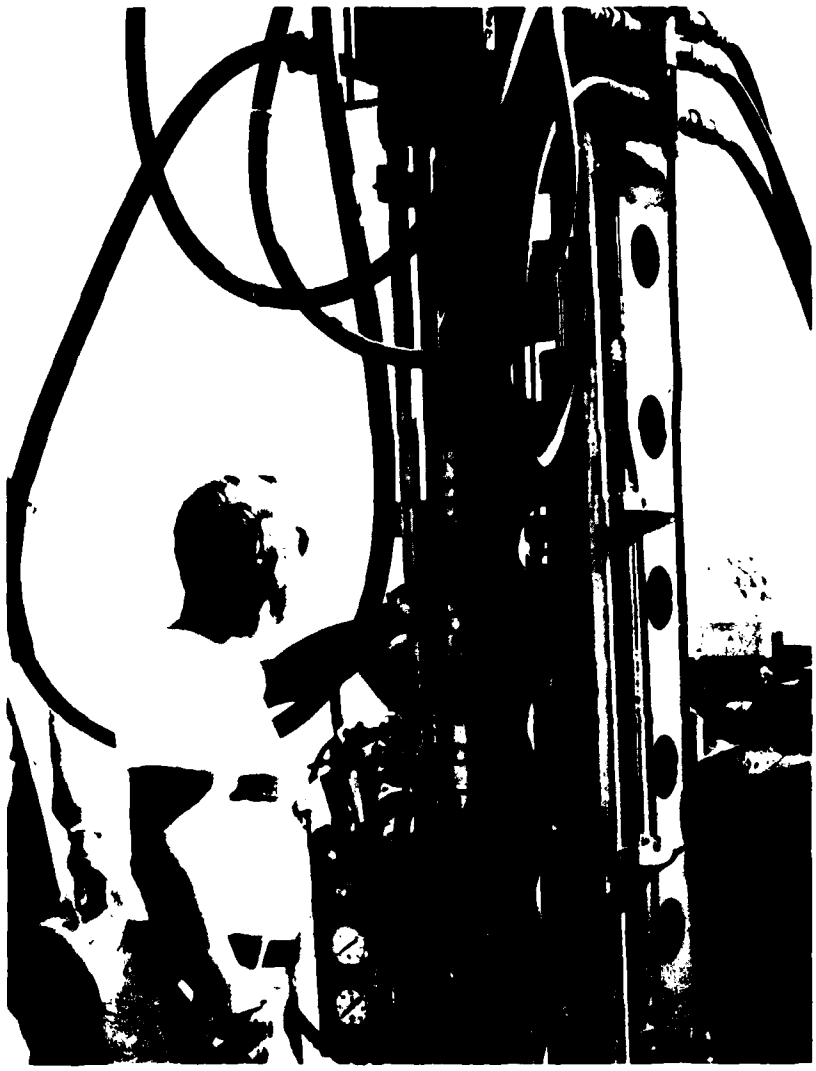

Figure 8. Plumbing Drill Collar to Obtain Borehole Verticality

The installation was then completed as follows:

- The rig hold-downs were tightened.
- The pipe rack was set up and loaded.
- The cuttings deflector was positioned and staked in place.
- The rock drill oil and pipe dope were made ready.
- The compressor units were started and allowed to warm up.

The borehole was begun using the drag bit at approximately 11:30 a.m. on 2 October 1979. After one to two feet of penetration, a competent hard formation was reached and rig vibration increased significantly. The drag bit was retrieved and the hammer drill was rigged. The remainder of the borehole was drilled using the hammer drill. Figure 9 shows the equipment during normal operation. Figure 10 shows the addition of a joint of drill casing to the tool string.

During the drilling of the borehole, a penetration rate of 6 to 8 inches per minute was maintained with the hammer drill. The borehole was completed to a depth of 88 feet (26.8 meters) at approximately 4:20 p.m. on 2 October. The hammer drill was retrieved by 5:10 p.m. and the casing string run in by 6:25 p.m. Figure 11 shows the configuration of the rig used to set the casing string. The borehole casing is shown on the pipe rack in the foreground. Note that the drive head has been pivoted clear of the derrick to allow the catline to be used for casing run-in.

Figure 12 shows the casing float shoe and first joint of casing ready for installation in the borehole. On 3 October the NW drill rod slips adapter was screwed into the landing joint of the casing and the vertical deviation of the borehole was measured using an A-1 Bit and Tool Company Model A Sure-Shot deviation meter. Two runs were made with the deviation meter to verify the measurement. The vertical deviation of the borehole was found to be 1° on both runs.

The casing was then cemented in place using a 12 pound neat cement slurry. Six sacks of cement mixed in three separate batches were used. Figure 13 shows the cement slurry being mixed.

The drive head was pivoted back into its operating position and a section of NW drill rod was mounted on the drive pin. All of the cement mixture was then poured into the casing (see figure 14). The NW drill rod was used to push a 4.5 inch Halliburton rubber cement wiper plug down on top of the cement, forcing the cement out of the float shoe and up into the borehole annulus (see figure 15). When the cement plug was seated on top of the float shoe, the drive head was disconnected from the top joint of the push rod and raised a few inches to check for movement of the cement plug. After approximately five minutes of waiting, it was verified that the cement plug had not moved and the NW rod was recovered.

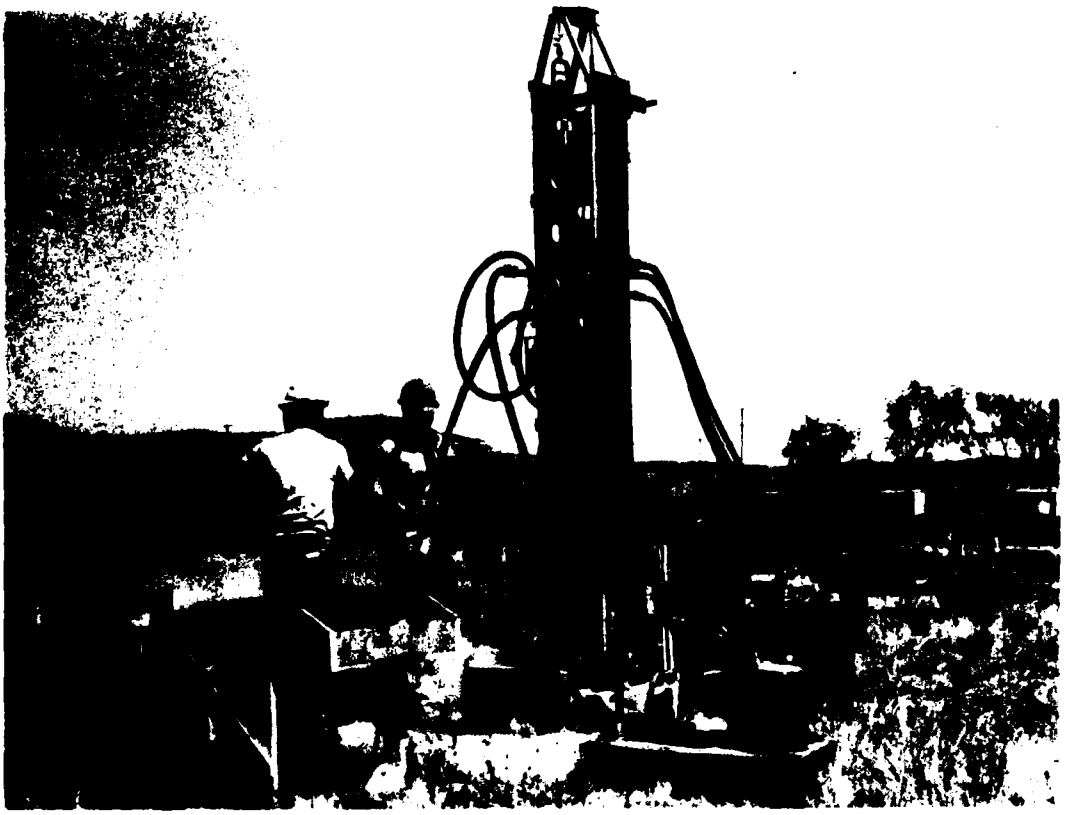

Figure 9. Normal Operation During Field Tests With Hammer Drill

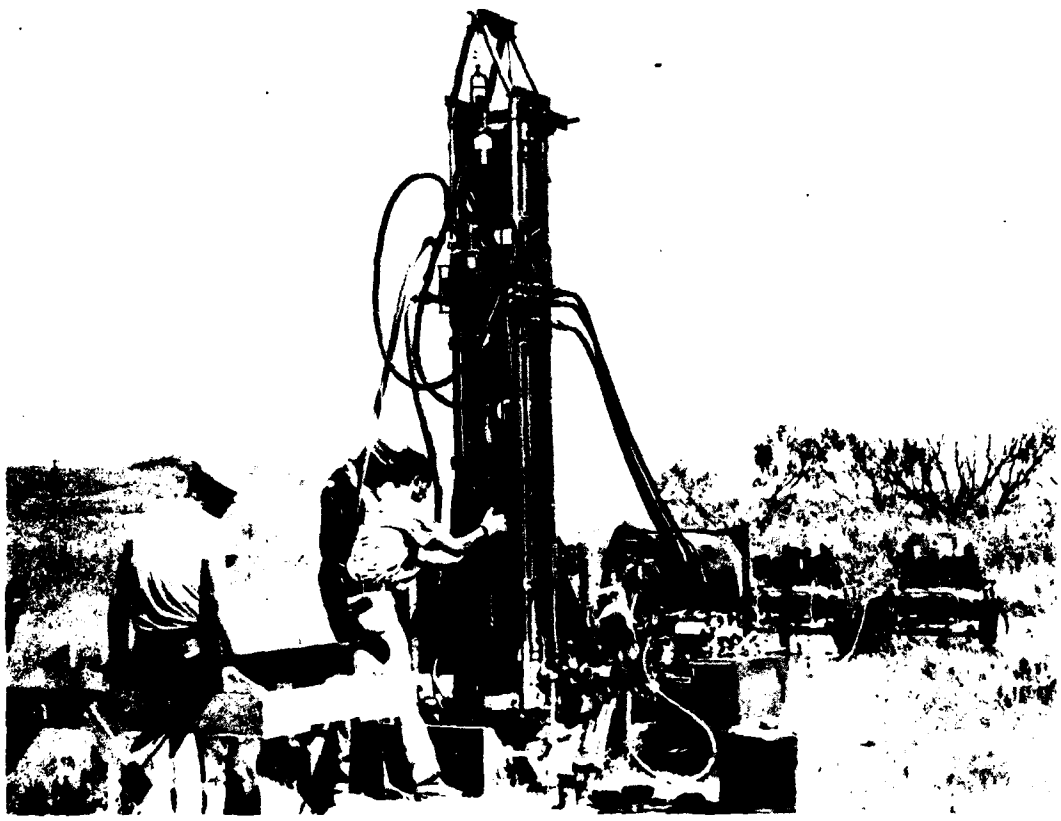

Figure 10. Addition of a Joint of Drill Casing to Tool String

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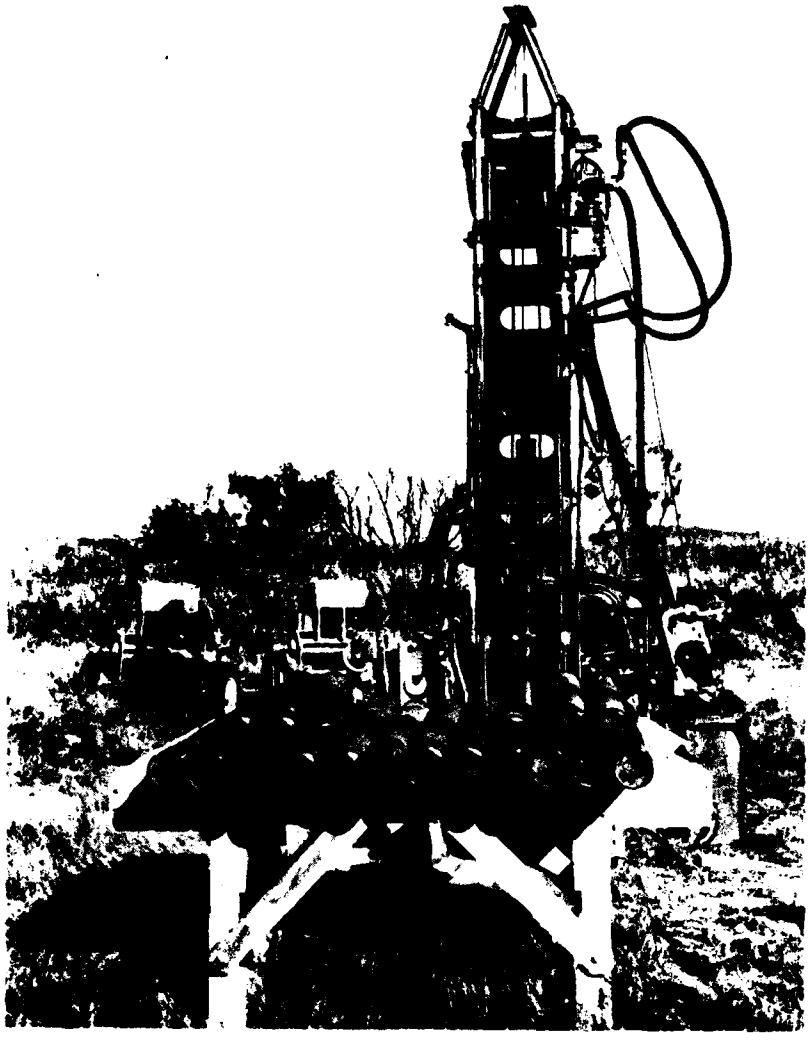

**Figure 11.** Configuration of Rig Used to Run in Borehole Casing. Note That Drive Head Has Been Pivoted Clear of the Derrick to Allow Use of the Catline

Figure 12. Casing Float Shoe and First Casing Joint Ready for Run-in

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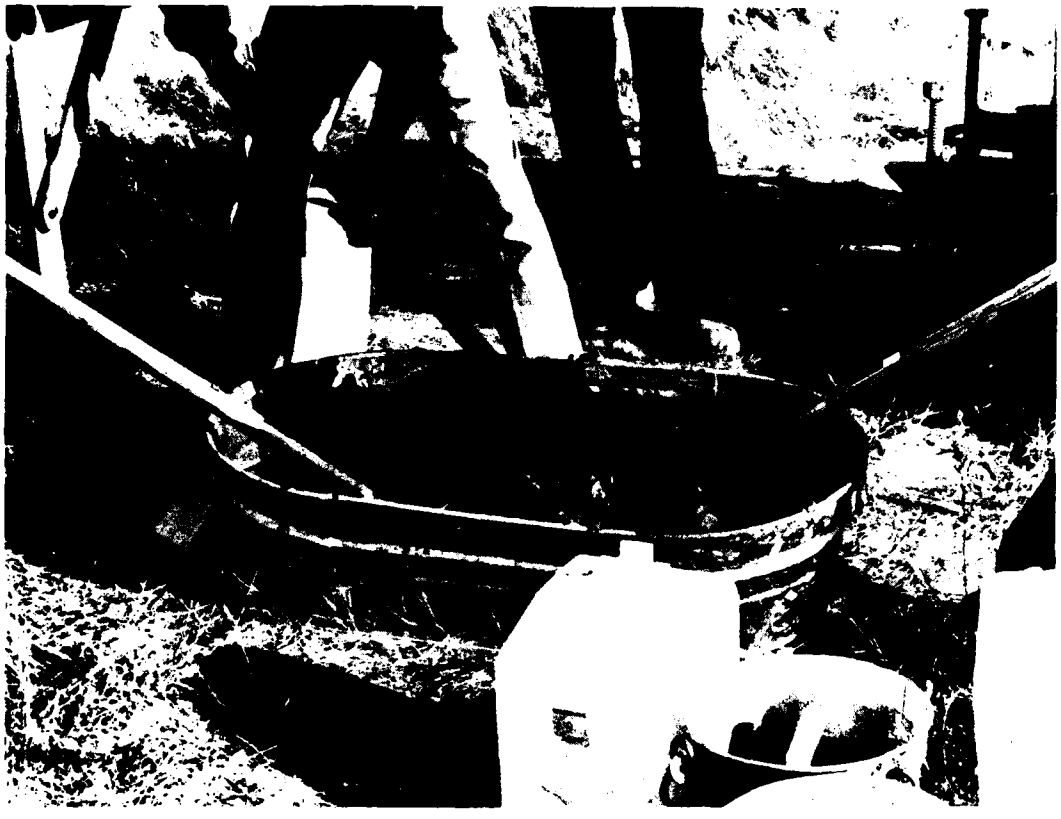

**Figure 13.** Cement Slurry Being Mixed. Three Batches as Shown Were Required for the Test Borehole

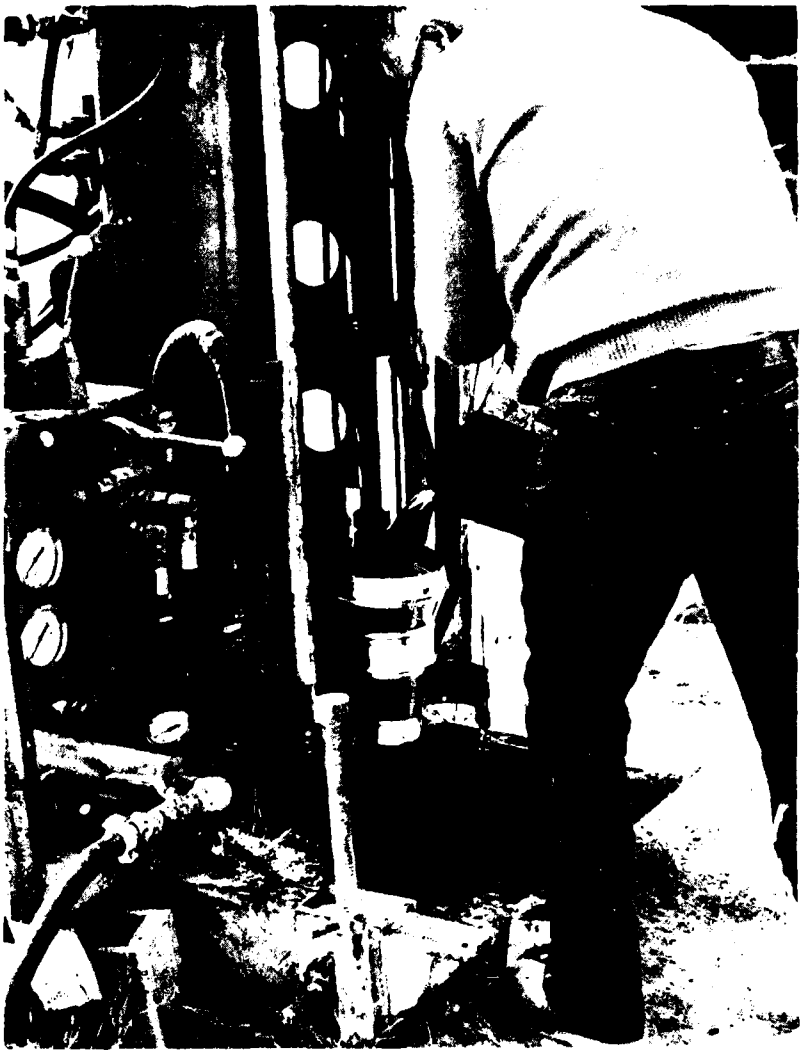

Figure 14. Pouring Cement Slurry into Borehole Casing

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Figure 15. Cement Slurry Return Around Annulus of Casing

Figure 16. Installation of Calseal Finishing Cement Using Bottom Dump Bailer

Figure 17. Capping Borehole Casing

The rig was disassembled and the trucks reloaded in preparation for departing the site. When the borehole area had been cleared, approximately two gallons of Calseal, using a two-to-one ratio of Calseal to water, was mixed and poured into a bottom dump bailer (see figure 16). The bailer was lowered into the casing and the Calseal dumped on top of the cement plug. The casing was then capped as shown in figure 17 and the site cleared of all debris.

## 4. SUMMARY

The performance of the drill rig was found to be entirely satisfactory except for three minor problems discussed in the following paragraphs. Its performance met or exceeded specified requirements in the following areas:

- o Borehole depth. The specified requirement was a minimum of 15.5 meters (50 feet). The test borehole was completed to 26 meters (86 feet).

- o Vertical deviation. The specified requirement was less than seven degrees. The deviation of the test borehole was one degree.

- o Penetration rate. The penetration was unspecified, however the nearly constant penetration rate of six to eight inches per minute exceeded expectations.

- o Casing clearance. Casing clearance was unspecified, however it was evident during casing run-in and subsequent cementing operations, that the clearance between the walls of the drilled borehole and the outside diameter of the casing was more than adequate.

The most significant problem encountered during the field tests was the tendency of the Chicksan coupling to become loosened by the rotation of the drive head during normal drilling. It is suspected that this coupling had not been tightened securely prior to beginning field tests, thus causing the failure. Therefore, in addition to periodically checking the tightness of the joints of this assembly, a restraint chain was designed and installed that will prevent separation between the air line and the drive head should this coupling become loose in the future.

The rig hold-down and anchors were found to be inadequate to withstand the forces which could be applied to them. In discussions with Project Office personnel, it was decided that the temporary anchors would be abandoned and permanent anchors would be installed prior to the arrival of the drill rig on site. The rig hold-down design was strengthened and reinforced to prevent bending, but new hold-down units were not fabricated under the contract.

The third problem encountered was caused by the column of air trapped between the cement wiper plug and the cement inside the casing during borehole completion. This column of compressed air required that the drill rods used to push the wiper plug down be restrained whenever a new drill rod was added. No arrangements had been made to provide the needed restraint and, therefore, an unsafe condition resulted.

It was decided that a new cement wiper plug will be designed which incorporates a ball check valve to relieve the air pressure in the borehole as the plug is being forced down on top of the cement column. When the plug reaches the cement column, the ball will seat in the check valve and prevent the leakage of cement past the plug. A prototype unit was designed but not fabricated and tested under the contract.

Preliminary set-up and operating procedures for the equipment are contained in Appendix 1. These procedures have not been proven by actual field use. Appendix 2 contains a list of spare parts purchased for the drill rig and air compressors, and Appendix 3 contains a list of recommended tools needed for the operation of the rig.

APPENDIX 1 to TECHNICAL REPORT NO. 79-14

PRELIMINARY DRILLING PROCEDURES

# 1. PRELIMINARY DRILLING PROCEDURES

## 1.1 SETUP AND ASSEMBLY OF DRILL RIG

1.1.1 Clear and level the area at the borehole location as shown in figure 1-1. Position the rig substructure and place the leveling jack plates in their proper positions under the jack screws. Extend the jack screws until the wheels of the rig are clear of the ground surface. Remove all four wheel units. Position the control unit near the front of the substructure and remove the lifting handles and the skids from the rear of the unit.

1.1.2 Place the four stands near the control unit and lift the control unit onto the jack stands. The jack stands should be positioned in the second notch from the top.

--CAUTION--

The control unit must be stabilized to prevent it from tipping over as it is unbalanced toward the control box side. If left unattended it is not stable on the jack stands.

1.1.3 Remove the two wheels from the control unit. Install the two carrying handles on the wheel axles and place the control unit on top of the substructure with one handle resting on the air manifold and the other handle resting on the opposite skid.

1.1.4 Lift the control unit, remove the carrying handles, and position it between the six mounting brackets welded to the substructure. Install the ten 3/8-inch bolts to attach the control unit to the substructure.

1.1.5 Position the derrick at the rear of the substructure and place it on the four jack stands. Place the double length extension handles on the derrick in place of the wheels and install it on top of the control unit. This procedure requires several people. Six people minimum are required to lift the derrick high enough to clear the control unit, hoses and control handles; one person must install the hinge pins in the top of the control unit; and another person is required to insert the support bar at the rear of the substructure. Remove the axle assembly from the lower end of the derrick once it has been installed in place. Raise the derrick to its upright position and place the locking pins and wave pin keepers in place at the base of the derrick.

1.1.6 Position the main engine at the rear of the substructure and place it on the jack stands. Remove the wheels and place the carrying handles on the wheel axle stubs on all four corners of the main engine unit. Lift the main engine into place and position it on the engine mounts at the rear of the substructure. Remove the carrying handles and lock the engine into place on its mounts. Position the drive head at the front of the substructure near the base of the derrick. Install the drive head on the derrick using the two 1/2-inch bolts and the break-away handle.

--CAUTION--

Do not attempt to start the main engine of the drill rig until after all hydraulic lines have been connected. Rotation of the main hydraulic pump without proper line connections will damage this unit beyond repair.

1.1.7 Install the hydraulic lines from the drive head to the connectors on the side of the derrick.

1.1.8 Position the hydraulic reservoir tank near the side of the rig opposite the control unit and just behind the derrick. Connect the hydraulic lines to this tank in the following manner:

a. Both return lines to the center connections. Location of these lines with respect to a specific connector is not important.

b. The main pump return line to the main pump (this line is attached to the left hand connection of the tank opposite the filler cap).

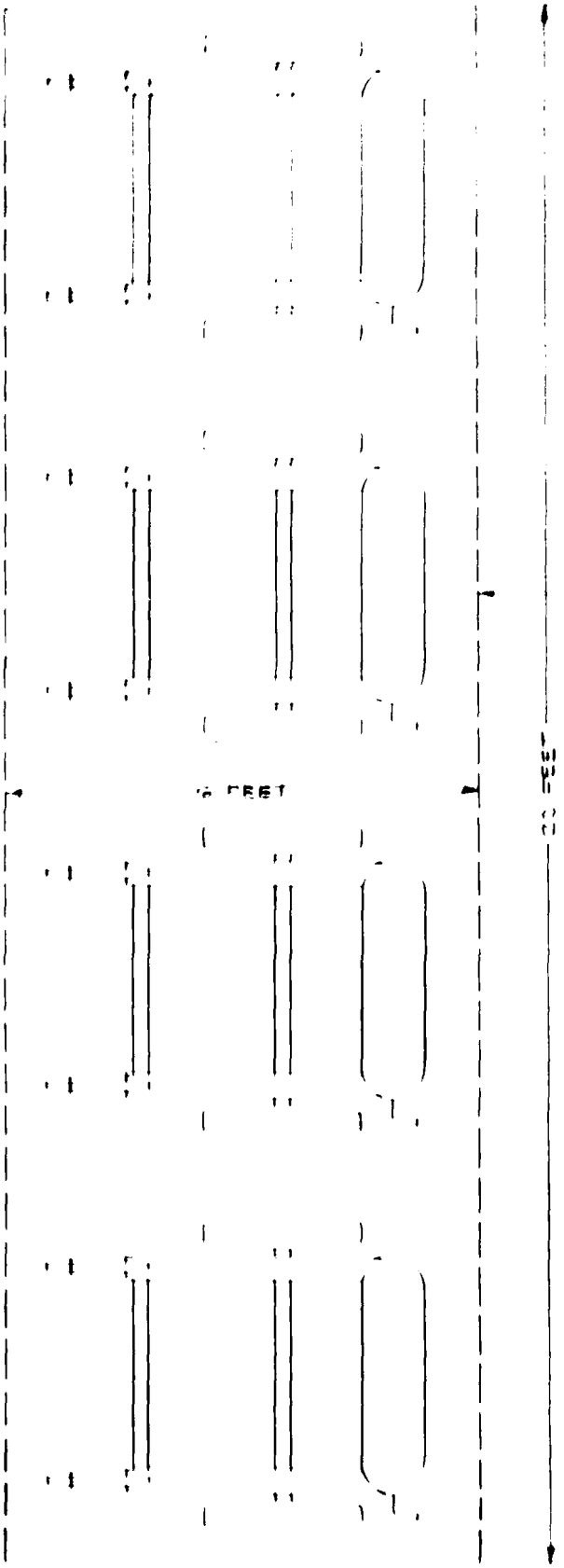
1.1.9 Connect the two hydraulic lines to the hydraulic ram fittings on the side of the derrick just above the control unit. Install the direction control rod between the control unit and the main pump. Adjust the turnbuckle on this control rod to provide zero rotation of the drive head when the control lever is centered (against the red, mechanical stop). This adjustment must be made with the engine running and should be repeated until a stable position has been achieved.

1.1.10 Install all of the air lines between the compressors and the air manifold, from the manifold to the derrick, and from the derrick to the drive head. Check the restraint between the air line and the drive head and install retainer pins on all air line connections.

--WARNING--

Failure to install restraints and retainer pins on all air line connections creates a hazardous condition which can cause personnel injury or death if one of these connections should fail under pressure during the operation of the rig.

1.1.11 Install the drag bit and the drill collar on the drive head of the rig and lower it to a point where the drag bit is just above the slips bowl. Position the dust deflector so that the bit is centered directly above the slips bowl and install the two stake pins at the rear of the dust deflector. Adjust the jack screws to lower the rig until the skids are just above the ground surface and level it in all directions using a level against the drill collar to determine when verticality is achieved.



CLEAR AND LEVEL AREAS
DEFINED BY DOTTED LINES

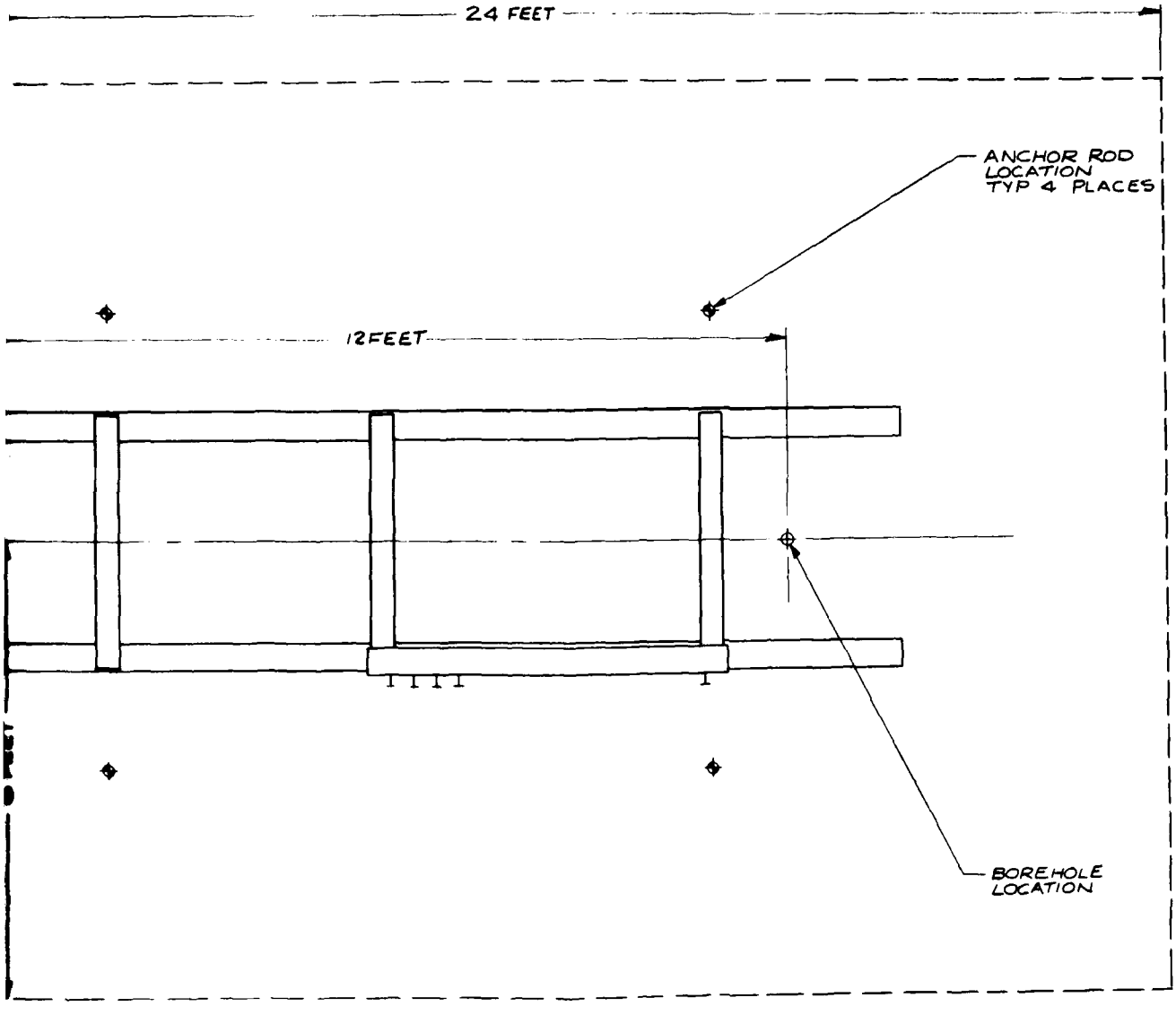
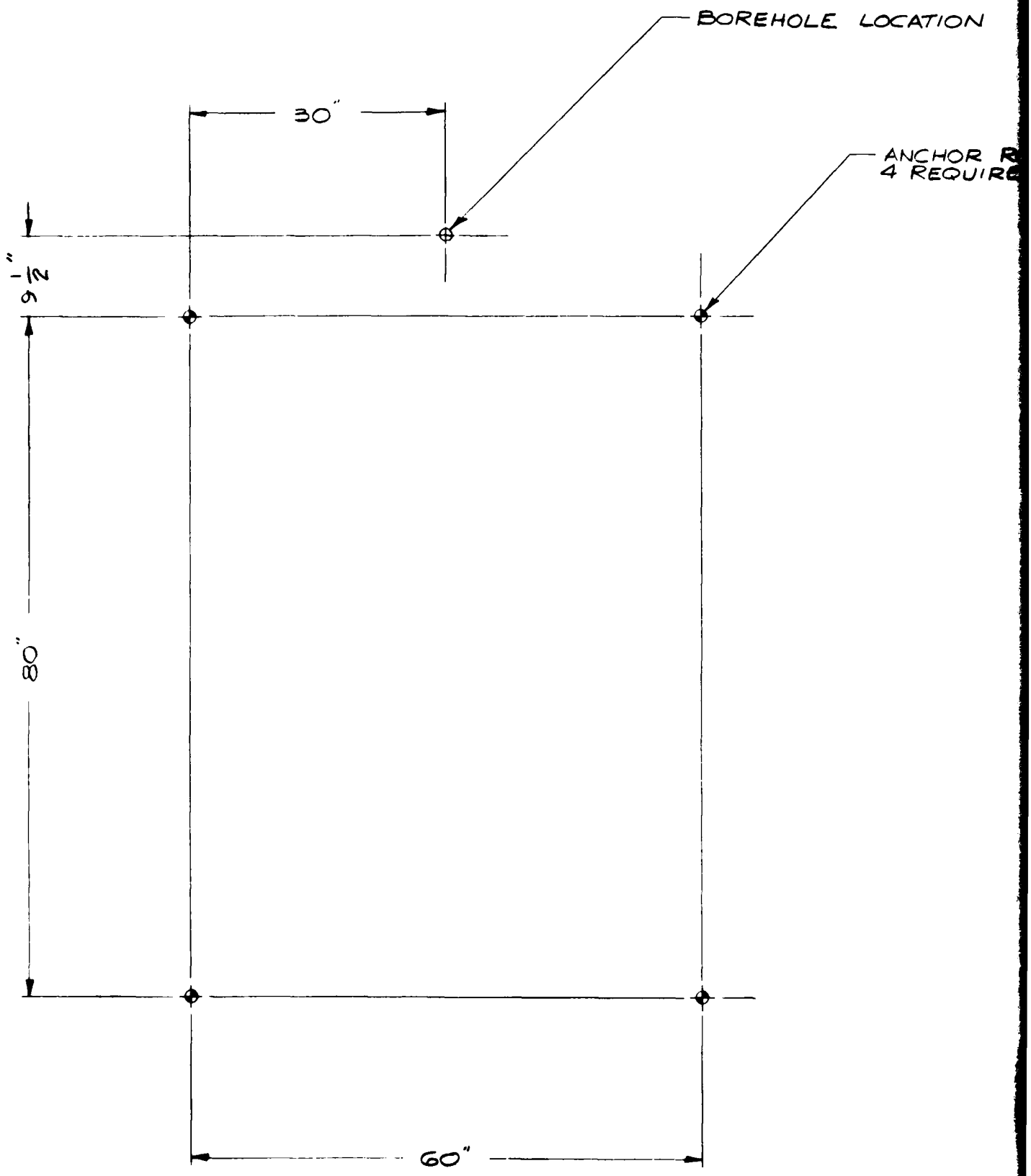
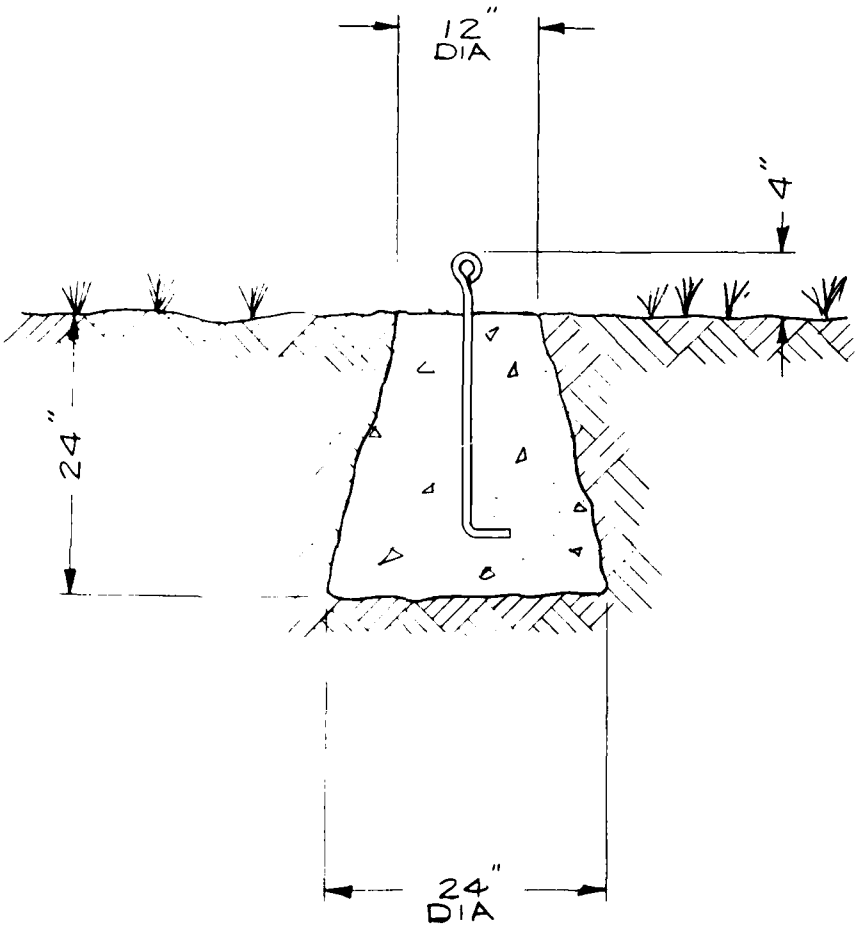



Figure 1-1. Site preparation for portable drill rig




ANCHOR ROD PLACEMENT
FOR DRILL RIG TIE DOWNS

ROD LOCATION
RED




TYPICAL ANCHOR ROD
INSTALLATION

Figure 1-2. Rig hold down anchor locations

--NOTE--

The bottom of the drill collar must be centered inside the guide shoe at the bottom of the derrick when the rig is leveled.

1.1.12 If permanent rig hold-down anchors have not already been installed, install temporary anchors as follows:

a. Mark the anchor locations as shown in figure 1-2.

b. Install the rig hold-down brackets in the front and rear box beams of the substructure and secure them using two one-half inch diameter, T-handle pins in the base of each hold-down bracket.

c. Set one or more anchors at each anchor point by driving in the spear rod using the air impact tool and then removing the spear using a special, modified Kellum grip and the rig hold-down winch.

d. Load an assembled anchor rod and point in the anchor drive rod and install it in the hole left by the retrieved spear. Use the air impact tool for this installation.

e. Install a ring on each anchor rod and attach the hold-down winch cable to the anchor ring.

--NOTE--

Do not tighten the hold-down winch cables until after the rig has been properly leveled.

f. Tighten each winch until the hold-down cables are taunt and the anchors are secure in the ground.

1.1.13 Start the air compressors and allow them to warm up to full speed.

1.1.14 Start the main engine and allow it to warm up.

1.1.15 Install the wire line on the auxillary winch as follows:

a. Thread the loose end of the wire line up through the crown block sheaves from the front of the rig.

b. Route the line behind the top carrying bar axle at the rear of the derrick and down between the wire line winch drum and the derrick.

c. Feed the end of the cable through the loop on the winch drum and pull approximately eight inches of excess cable through this eye.

d. Lay the excess cable across the length of the drum and start the winch in the take-up direction by raising up on the winch control lever.

e. Maintain tension on the wire line and guide it onto the drum to obtain a smooth, layered wrap.

f. When the clevis end of the wire line is reached at the front of the derrick, install the catline adapter and continue to reel up the line until the adapter is pulled up to within a few inches of the crown block.

1.1.16 Load the pipe rack with ten sections of casing and the hammer drill.

1.1.17 This completes the initial set up of the drill rig.

## 1.2 BOREHOLE DRILLING PROCEDURE

1.2.1 In areas where there is overburden present, the drilling operation should begin using the stepped drag bit and drill collar. The rotational speed of the drill rig must be adjusted to minimize bit chatter and rig vibration. In softer formations, the rotational speed may be increased. In harder formations, the rotational speed must be reduced to a few revolutions per minute. The rotational speed must be adjusted by the vertical lever on the left side of the control unit. Moving the lever toward the operator rotates the bit in the drilling direction (i.e., clockwise, looking downhole). Releasing the red, mechanical stop and moving the vertical handle away from the driller reverses the direction of rotation and is used when breaking joints to add or remove drill stem. The rate of penetration is adjusted by the black control valve on the top of the control unit and the direction of drive head movement is determined by the lever on the top of the control unit near the black control valve. Moving this lever forward, away from the operator, applies pulldown (crowd) to the drive head and is the position normally used during drilling.

--NOTE--

The drive head direction control lever can be locked in the crowd direction and is normally operated in this position when using either of the drill bits. Moving the lever in the opposite direction (toward the operator) causes the drive head to move upward toward the top of the derrick and this position is used when a new piece of drill stem is added or when the tool string is being retrieved.

1.2.2. The red-handled valve on the air manifold below the control panel controls the air flow used to operate the hammer drill and clean the borehole. The lever on the front of the control unit near the operator operates the auxillary winch (catline) and is used only when this line is in service.

1.2.3 Begin the drilling operation using the drag bit to penetrate the overburden. Adjust the crowd on the bit to a minimum, the rotation to approximately one-third maximum rpm and the circulation air to a maximum. When drilling in overburden or other soft material, the penetration rate should be maintained at a minimum and rotation should be maintained at approximately 1/3 to 1/4 maximum rpm. Continue drilling with the drag bit until a hard formation is reached and cannot be easily penetrated. During this period, approximately one to two gallons of water may be required for each five to ten feet of penetration in order to seal the sides of the borehole and prevent sluffing.

1.2.4 When a hard formation has been reached, the drill casing, drill collar and drag bit should be recovered and the hammer drill should be rigged. Use the drill casing as a drill collar when drilling with the hammer drill. Apply circulation air prior to lowering the hammer drill in the hole and begin rotation before enough crowd is applied to close up the hammer and begin drilling. Sufficient crowd should be applied to keep the hammer closed up and hammering at approximately 1200 strokes per minute. Excessive crowd will cause the hammer to stop operating and insufficient crowd will cause the hammer to lock up in the extended position and can cause damage. As deeper and deeper penetration is achieved and more drill stem is added to the tool string, the amount of crowd must be decreased to prevent overriding the hammer. The penetration rate should be continuously monitored and adjusted for approximately six to eight inches per minute. One inch markings are visible on the left guide rail of the derrick on which the drill head is mounted for use in monitoring penetration rates.

1.2.5 When sufficient drill stem has been added to the casing string to cause excessive penetration rates under its own weight, holdback pressure must be applied to control the penetration rate and maintain a six to eight inch per minute penetration. Holdback is applied by turning the round control valve in the upper left hand corner of the control unit on the side near the driller clockwise. This control valve must be continuously adjusted to increase holdback as the drill stem is added.

--CAUTION--

Assure that adequate circulation of the air is maintained throughout the drilling procedure. Failure to do so will cause an obstruction to form above the drill bit which can prevent recovery of the hammer drill.

1.2.6 Drilling depths in excess of 30 meters will exceed the holdback capability of the rig and should not be attempted.

--WARNING--

Gloves and other protective devices must be worn during the drilling operation to prevent severe burns which could be caused by the extremely hot air used for circulation.

1.2.7 Uncrate the A-1 Sure-Shot Deviation Tool and attach a 3/8-inch nylon line, sufficient in length to reach the bottom of the borehole. Assemble the shock mount and the lower centralizer assembly of the deviation tool and install it on the barrell assembly. Remove the bottom of the time unit and install an unused aluminum disk under the clamp ring of this assembly. Pull out the top handle and set the time for 10 to 15 minutes. Reinstall the lower disk holder assembly and insert the timing unit into the barrell of the deviation tool. Install the upper centralizer and subassembly and lower the entire unit into the borehole until it reaches total depth. Wait a minimum of 15 minutes and retrieve the deviation tool. Disassemble the unit to obtain access to the readout disk and remove the disk. Read the deviation directly in degrees by noting the position of the punch mark with respect to the lines inscribed on the aluminum disk. Repeat this procedure a minimum of two times or until readings in close agreement have been obtained. Disassemble the deviation tool and return it to its carrying case.

1.2.8 When total depth has been reached and the borehole verticality has been verified, the drill string should be retrieved to recover the hammer drill. As the casing is removed from the borehole, it should be placed back on the pipe rack in five foot sections. The catline is normally used for this purpose.

## 1.3 CASING THE BOREHOLE

1.3.1 After the borehole has been drilled to the desired depth, the hammer drill must be retrieved before the borehole casing can be installed. Either the drive head or the catline can be used to pull the drill stem. However, the catline is recommended as it is normally more convenient to use.

1.3.2 Disconnect the air line from the drive head. Release the drive head by removing the release handle on the left guide rail mount and swing the drive head outward. Attach a line to the drive head and raise it to its top position in the derrick. Tie the drive head in its out position so that it does not interfere with the operation of the catline.

1.3.3 Attach the catline adapter to the top joint of the drill stem and engage all but one or two threads on the adapter pin. Raise the entire tool string until a casing joint is located above the guide shoe at the bottom of the derrick. Halt the upward motion of the tool string and engage the slips around the casing, below the guide shoe, using the air impact wrench to tighten the slips clamp. Lower the tool string until the slips seat in the slips bowl and, using a pair of 48-inch pipe wrenches, break the joint between the upper and lower pieces of drill stem. Unscrew the top piece of drill stem while maintaining a slight upward pressure on the catline until it comes free of the tool string. Place the loosened section of stem on the pipe rack and remove the catline adapter. Install the catline adapter on the top joint of the casing still in the borehole. Raise the tool string until the slips are clear of the slips bowl and loosen the slips clamp bolt using the air impact wrench. Remove the slips and set them on top of the slips bowl so that they will be in position for the next clamping operation. Repeat this procedure until all of the drill stem and the hammer drill have been removed from the borehole.

1.3.4 Place the float shoe on the lowest section of casing and attach the catline adapter to the box end of this casing joint. Raise the entire assembly into the derrick and lower it into the borehole until the catline adapter is between six inches and a foot above the guide shoe at the bottom of the derrick. Place the slips clamp in the slips bowl and tighten it around the casing using the impact wrench.

1.3.5 Remove the catline adapter from the top of the casing section and install it in the box end of the next casing joint. Lift this casing joint into the derrick and thread it into the top of the casing string installed in the borehole. Tighten the joints with the 48-inch pipe wrenches. Raise the casing string so that the slips clamp clears the slips bowl and remove the clamp using the impact wrench. Set the clamp on the slips bowl so that it will be ready for the next clamping operation. Continue to add casing in this manner until the float shoe tags bottom at total depth. Return the catline to its top most position in the derrick and return the drive head to its normal mounted position. Raise the drive head to its maximum height in the derrick and shut down the rig.

1.3.6 Restart the main engine and lower the drive head to a convenient working height. Remove the NW to HW adapter from the drive pin on the drive head. Install a five foot length of 2-3/8 inch drill rod on the drive head and raise the drive head to its maximum height in the derrick. Remove the dust deflector. If it is necessary to raise the rig to remove the dust deflector, ensure that the hold-down cables are retightened and the rig is releveled before proceeding with the borehole completion procedure.

## 1.4 BOREHOLE COMPLETION

1.4.1 The final operation is to cement the borehole casing in place over its entire length. The total amount of cement, plus a safety factor of from 25 to 50 percent in volume, must be computed for the depth of the borehole drilled. Install the drill rod slips bowl adapter on the top section of the casing. Using a suitable container, mix a neat cement slurry of between 13 and 14 pounds per gallon weight (7 to 9 gallons of water per 94 pound sack of cement) and pour the slurry into the borehole casing.

--NOTE--

A 14 pound per gallon slurry will occupy a volume of 1.5 cubic feet. For a 25 meter borehole, six sacks of cement and 40 to 45 gallons of water should be used.

1.4.2 When all of the cement slurry has been poured into the casing, mount a rubber cement wiper plug on the top of the slips adapter and push it into the bore of the casing using the drive head and a five foot section of 2-3/8-inch drill rod. When the drive head is approximately 1 to 1-1/2 feet above the top of the casing, install the drill rod clamp and lower it into its seat in the adapter. Using the 48-inch wrenches, break the connection between the 2-3/8 inch drill rod and the drive head and mount another five foot piece of rod on the push rod string in the borehole. Continue this procedure until the plug has been forced to its lowest position on top of the float shoe.

--NOTE--

If air is trapped between the cement wiper plug and the cement column in the borehole, it will be compressed as the plug is forced down the bore. Restrain the slips clamp to prevent the drill rod from being forced back up the casing against the drive head.

1.4.3 When the cement plug has been pushed to its lowest position in the borehole, any air trapped between the plug and the cement column will be forced out through the float shoe and should bubble up around the annulus of the casing. When the plug bottoms out against the float shoe, the push-down pressure will significantly increase and can be seen on the pressure gauge measuring the amount of crowd applied to the drill rod.

1.4.4 Using the 48-inch pipe wrench, break the connection between the drive head and the top section of drill rod and raise the drive head approximately one to two inches above the drill rod. Carefully note the distance between the end of the drive head and the top of the drill rod and allow from five to ten minutes of wait time. If this distance does not change, then the plug and float shoe are verified to be holding and the drill rod can be withdrawn. If the drill rod is forced back up against the drive head, then the drill rod string should be retrieved and a new rubber cement plug should be run in immediately behind the first plug.

1.4.5 Withdraw the drill rod using either the catline or the drive head. If the drive head is used, loosen (but do not disconnect) the joint between the drive head and the drill rod before withdrawing the top section of drill rod from the borehole. After installing the drill rod clamp and lowering the clamp into the slips adapter, break the joint between the drill rods using the 48-inch pipe wrenches.

--CAUTION--

If deviations from the above procedures are attempted, failure to restrain the lower end of the drill rod or borehole casing when breaking the drive head joint can result in irreparable damage to the drive head.

1.4.6 Mix approximately 10 pounds of Calseal, using a slightly less than 2 to 1 Calseal to water ratio by volume, and pour the slurry into the top of the bailer. Assure that the bottom valve of the bailer remains closed during this operation. Attach a nylon line to the bailer and lower it into the borehole until it rests on the bottom plug. Wait several seconds for the bailer to empty and then slowly withdraw it leaving the slurry of Calseal in the bottom of the hole. Immediately clean up all tools used for cementing and completion using water and a cloth to assure that all cement and Calseal is removed. Restore all tools to their respective transport positions and dismantle the rig as described below.

## 1.5 DISASSEMBLY OF THE DRILLING RIG

1.5.1 When the borehole has been completed, the drilling rig should be disassembled in the following manner.

1.5.2 Lower the drive head to its lowest point of travel. Lower and remove the catline adapter and spool off all the catline from the auxillary winch. Shut down all engines. Position the four jack stands near the rear of the sub-structure and remove the derrick support at the rear of the main engine. Loosen the rig hold-down winches and disconnect the cable hooks from the rig hold-down eyes. Wind the hold-down cables onto the winch units.

1.5.3 Remove the 1/2-inch diameter pins securing the hold-down brackets to the substructure and remove the hold-down brackets. Remove all hydraulic lines and either reconnect them to mating connectors or cover exposed connectors with a protective plastic or a cloth bag to prevent the introduction of dirt into the connector. Install the carrying handles on the spindles of the main engine and loosen the four clamps which hold the engine in the engine mounts. Remove the engine and set it on the jack stands. Install the wheels on the engine and position it in a staging area for future transport. Remove the break-away handle and hinge pins from the drive head mount and remove the drive head. Place it in the staging area.

1.5.4 Remove the air lines from the air manifold and the compressor units and coil them up in the staging area. Move the compressor units to the staging area. Place the hydraulic oil reservoir tank in the staging area.

1.5.5 Reinstall the derrick support at the rear of the substructure and release the two locking pins at the bottom of the derrick unit. Lower the derrick until it rests on the derrick support bar and install the lower carrying handle bracket assembly. Reinstall the locking pins in the substructure or in the derrick bracket so that they will not be lost. Install the double length carrying handles on each end of the derrick unit and remove the derrick, placing it on jack stands at the rear of the substructure assembly.

--CAUTION--

> The removal of the derrick requires a minimum of six to seven people as the weight of this unit is excessive for fewer people to handle with safety. Removal should not be attempted until this number of people can be made available.

1.5.6 Install the wheels on the derrick and place it in the staging area. Remove the ten 3/8-inch bolts attaching the control unit to the substructure and place the carrying bar axle of the control unit on the air manifold and opposite skid.

1.5.7 Install the carrying bars on each end of the control unit carrying axle and place the steering handles in the sockets provided at the rear of the unit. Lift the control unit using the carrying bars and steering handles. Place the control unit on the jack stands and install the wheels on the axles of the unit.

--CAUTION--

The control unit is heavily unbalanced toward the control box side and must be supported until it is mounted on its wheel assemblies.

1.5.8 Install the two skids at the rear of the control unit and place it in the staging area.

1.5.9 Raise the jack screws on the rig substructure sufficiently to allow the wheels to be placed on this unit and move it to a staging area.

1.5.10 Remove and store the components remaining on the pipe rack and place them in the staging area. Remove the four 5/8-inch bolts from the top of the pipe rack leg assemblies and fold the pipe rack and place it on the staging area.

1.5.11 Remove the drill rod slips adapter from the landing joint of the casing string. Apply pipe dope to the threads of the casing cap and tighten the cap on the landing joint of the casing using the 48-inch wrenches. Restrain the casing when tightening the casing cap.

APPENDIX 2 to TECHNICAL REPORT NO. 79-14

LIST OF SPARE PARTS
FOR
DRILL RIG AND AIR COMPRESSORS

## DRILL RIG SPARE PARTS LIST

| ITEM NO. | PART NO. | NOMENCLATURE | QUANTITY |
|---|---|---|---|
| 1. | 14-161 | Pin, drill pipe guide ass'y | 1 |
| 2. | 14-20 | Fiber washer, drill head ass'y | 1 |
| 3. | 14-294 | Split lock washer, drive head ass'y | 1 |
| 4. | 14-352 | Circular clip (C-ring), water air swivel | 1 |
| 5. | 14-348 | Circular clip (C-ring), water air swivel | 1 |
| 6. | 14-350 | Spacer, water air swivel | 1 |
| 7. | 14-65 | O-ring, pull down cylinder | 1 |
| 8. | 14-62 | O-ring, pull down cylinder | 1 |
| 9. | 14-60 | Rod wiper, pull down cylinder | 1 |
| 10. | 14-238 | Shaft seal, pull down cylinder | 1 |
| 11. | 14-346 | Packing gland, water air swivel | 1 |
| 12. | 14-10 | Circular clip (C-ring), drive head ass'y | 1 |
| 13. | 14-17 | Key, drive head ass'y | 1 |
| 14. | 14-11 | Bearing, drive head ass'y | 1 |
| 15. | 14-7 | Bearing, drive head ass'y | 1 |
| 16. | 14-63 | Wear ring and seal, pull down cylinder | 1 |
| | 14-64 | Wear ring and seal, pull down cylinder | 1 |
| 17. | 14-291 | Seal, drive head ass'y | 3 |
| 18. | G7CS(Charlyn) | Seal kit, hydraulic motor | 1 |
| 19. | 14-349 | Bearing, water air swivel | 2 |
| 20. | G7KS(Charlyn) | Seal kit, hydraulic motor | 1 |
| 21. | | Miscellaneous spare parts for air hammer | 1 kit |
| 22. | 14-202 | Clamp, hydraulic hose | 7 |
| 23. | | Repair kit, hydraulic pump drive head | 1 |
| 24. | 14-335 | Mount, drill rig engine | 2 |

| ITEM NO. | PART NO. | NOMENCLATURE | QUANTITY |
|---|---|---|---|
| 25. | 111 903 137 D | VW Fan belt, generator | 1 |
| 26. | 111 903 137 D | VW Fan belt, generator | 1 |
| 27. | 111 903 137 D | VW Fan belt, generator | 1 |
| 28. | 111 903 137 D | VW Fan belt, generator | 1 |
| 29. | 111 903 137 D | VW Fan belt, generator | 1 |
| 30. | 111 903 137 D | VW Fan belt, generator | 1 |
| 31. | 111 903 137 D | VW Fan belt, generator | 1 |
| 32. | 111 903 137 D | VW Fan belt, generator | 1 |
| 33. | 113 198 031 | Oil strainer gasket, VW engine | 1 |
| 34. | 113 198 031 | Oil strainer gasket, VW engine | 1 |
| 35. | 113 198 031 | Oil strainer gasket, VW engine | 1 |
| 36. | 113 198 031 | Oil strainer gasket, VW engine | 1 |
| 37. | 113 198 031 | Oil strainer gasket, VW engine | 1 |
| 38. | 1600A 61150 | Fuel tank shutoff valve and inline filter, VW Engine | 1 |
| 39. | 1600A 61150 | Fuel tank shutoff valve and inline filter, VW Engine | 1 |
| 40. | 14-335 | Engine mount, main engine on drill rig | 2 |
| 41. | 14-3 | Drive pinion, drive head | 1 |
| 42. | 122 135 171 | Tooth belt, drill rig motor governor | 1 |
| 43. | 122 135 171 | Tooth belt, drill rig motor governor | 1 |
| 44. | 122 135 171 | Tooth belt, drill rig motor governor | 1 |
| 45. | 113 101 481 F | Valve cover gaskets, VW engine | 2 |
| 46. | 113 101 481 F | Valve cover gaskets, VW engine | 2 |
| 47. | 113 101 481 F | Valve cover gaskets, VW engine | 2 |
| 48. | | VW tune-up kit, spark plugs, and point set | 1 |
| 49. | | VW tune-up kit, spark plugs, and point set | 1 |

| ITEM NO. | PART NO. | NOMENCLATURE | QUANTITY |
|---|---|---|---|
| 50. | 111 198 007 | Valve grinding gasket set, VW engine | 1 |
| 51. | 12B 251 157 | Exhaust system gasket set, VW engine | 1 |
| 52. | 14-22 | Spacer, drive head ass'y | 1 |
| 53. | 14-7 | Bearing, drive head ass'y | 1 |
| 54. | 14-16 | Bearing, retainer, drive head ass'y | 1 |
| 55. | 14-13 | Plate cover, drive head ass'y | 1 |
| | 14-12 | Gaskets,drive head ass'y | 1 |
| 56. | 14-8 | Bearing, drive head ass'y | 1 |
| 57. | 14-23 | Spacer, drive head ass'y | 1 |
| 58. | 14-6 | Lock nut, drive head ass'y | 1 |
| 59. | 14-5 | Shaft nut, drive head ass'y | 1 |
| 60. | 14-210 | Filter hydraulic return, drill rig | 1 |
| 61. | 12D 129 002 | Air filter element, VW engine | 1 |
| 62. | 12D 129 002 | Air filter element, VW engine | 1 |
| 63. | 14-211 | Suction filter, drill rig | 1 |
| 64. | 14-211 | Suction filter, drill rig | 1 |
| 65. | 14-4 | Drive shaft, drive head | 1 |
| 66. | 1075A 60960 | Air delivery cock | 1 |
| 67. | | NW drive pin, drive head | 1 |
| 68. | 1600A 60860 | Drain cock | 1 |
| 69. | | Fuel line hose, VW engine | 1 |
| 70. | 14-132 | Hinge pin, drive head mounting bracket | 1 |
| 71. | 14-319 | Drive head motor circuit | 4 |
| 72. | 14-201 | Hydraulic suction line to filter | 1 |
| 73. | 14-321 | Drive head motor circuit | 1 |
| 74. | 14-28 | Pulldown cylinder circuit | 2 |

| ITEM NO. | PART NO. | NOMENCLATURE | QUANTITY |
|---|---|---|---|
| 75. | 14-243 | Winch drive motor circuit | 1 |
| 76. | 14-244 | Winch drive motor circuit | 1 |
| 77. | 14-61 | Drive head pump circuit | 1 |
| 78. | 14-316 | Hydraulic return line | 1 |
| 79. | 14-200 | Pulldown cylinder pump input | 1 |
| 80. | 14-322 | Hydraulic return line | 1 |
| 81. | 14-323 | Hydraulic return line | 1 |
| 82. | 14-320 | Priority valve input | 1 |
| 83. | 14-211 | Drive head suction filter | 1 |
| 84. | | Connections, copper tube, compressor unloader group | 1 lot |
| 85. | 14-12 | Gasket, drive head cover plate | 1 |
| 86. | 14-2 | Drive gear | 1 |

| ITEM | PART NO. | NOMENCLATURE | QUANTITY |
|---|---|---|---|
| A | 1601B64020 | Gasket (inner) - head to valve | 2 |
| B | 1603B64010 | Gasket (outer) - head to valve | 2 |
| C | 1601B64040 | Gasket - valve to cylinder | 2 |
| D | 1600A62050 | Filter element - air intake | 2 |
| E | 1603A63910 | Plate - air delivery valve | 2 |
| F | 1603A63920 | Spring - delivery valve | 6 |
| G | 1603A63930 | Inner plate - inlet valve | 2 |
| H | 1603A63960 | Inner spring - inlet valve | 2 |
| I | 1603A63940 | Second plate - inlet valve | 2 |
| J | 1603A63970 | Second spring - inlet valve | 2 |
| K | 1603A63950 | Outer plate - inlet valve | 2 |
| L | 1603A63980 | Outer spring - inlet valve | 4 |
| M | 1603B63710 | Diaphragm - unloader | 2 |
| N | 1600C60700 | Speed control cylinder | 1 |
| O | 1603B60430 | Restrictor | 2 |
| P | 1603A62500 | Globe - warning light | 2 |

APPENDIX 3 to TECHNICAL REPORT NO. 79-14

Recommended Tool List

Appendix 3

Recommended Tool List

| | |
|---|---|
| 1 each | Plier Set (Sears 9HT45373) |
| 1 each | Wide Jaw Diagonal Cutting Pliers (Sears 9HT45074) |
| 1 set | 9 Piece Screw Driver Set (Sears 9HT41099) |
| 1 each | Flush Cut Hacksaw (Sears 9HT3559) |
| 1 each | 10-Inch Locking Plier-Wrench (Sears 9HT45341) |
| 1 each | Claw Hammer 16 oz. (Sears 9HT38141) |
| 1 each | Ball-Peen Hammer 24 oz. (Sears 9HT38466) |
| 1 each | Level 36-Inch (Sears 9HT39927C) |
| 1 each | Dwell/Tach Meter (Sears 28RY2177) |
| 1 set | Jumper Cables (Sears 28RY7114) |
| 1 each | Snap-on Oil Can Funnel (Sears 28RY4657) |
| 2 each | Flash Light, 2 "D" Type (Sears 34RY4413) |
| 1 each | Taper Heat Gauge .0015-.025 (Sears 9HT46696) |
| 1 each | Standard 20 Piece Hex Key Wrench (Sears 9HT46696) |
| 4 each | Malleable Iron Safety Blocks, Double Block, 6" Shell Length Type, McMaster-Carr 3125T with Bronze Bushings |
| 600 feet | Nylon Rope, 3/4" Dia., McMaster-Carr 382TT21 |
| 2 each | Aluminum Pipe Wrench (Sears 9HT55699) |
| 1 each | Mechanics Tool Box (Sears 9HT65141C) |
| 1 each | Regular-Head Ratchet Wrench, 3/4" Drive (Sears 9HT44801) |
| 1 set | 3/8" Drive Sockets, 3/8" to 13/16", Sears 9HT4389) |
| 1 set | 3/8" Drive Deep Sockets, 3/8" to 7/8" (Sears 9HT43156) |
| 1 set | 3/8" Drive Socket - Metric 9-19 mm (Sears 9HT4347) |
| 1 each | 3/8" Drive Ratchet Regular Head (Sears 9HT43785) |

| | |
|---|---|
| 1 each | 3/8" Extension 3" (Sears 9HT44264) |
| 1 each | 3/8" Drive Extension 6" (Sears 9HT44261) |
| 1 each | 3/8" Drive Extension 10" (Sears 9HT44262) |
| 1 each | 3/8" Drive Universal Joint (Sears 9HT4435) |
| 1 each | 3/8" Drive Spark Plug Socket 13/16" (Sears 9HT43321) |
| 1 each | 3/8" Drive Spark Plug Socket 5/8" (Sears 9HT43326) |